VISIBLE-BAND AND IUE OBSERVATIONS OF μ SAGITTARII

J. D. Dorren
Biruni Observatory, Shiraz, Iran

E. F. Guinan and E. M. Sion
Villanova University, Villanova, Pennsylvania 19085

ABSTRACT

Hα and u band photometry and IUE spectra of the binary system μ Sagittarii are discussed. An estimate of mass-loss is made from the observed P Cygni profiles. There are indications of pulsation in the supergiant B8 component.

We present Hα intermediate and narrow-band and u photometry, and IUE observations of the bright ($V = +3.86$) variable star μ Sagittarii (HR 6812, HD 166937, ADS 1169A), spectral classification B8 Iap.

Spectroscopic observations (ref. 1) suggest that it is a single-line spectroscopic binary of period 180.45 days with a highly eccentric ($e = 0.4$) orbit and with a mass function of $f(m) = 2.64M_{\odot}$, indicating massive components. The relative orbit is shown in figure 1 in which the supergiant component is at superior conjunction, defining 0.0 phase. Morgan and Elvey (ref. 2) reported an eclipse of the B8 supergiant lasting about 20 days with a depth of ~ 0.14 mag in V and constant light lasting ~ 11 days. The phase of minimum light coincided with the spectroscopic phase of superior conjunction of the B8 star.

No further photoelectric observations were available until those of Dorren and Guinan (ref. 3) at Biruni and Villanova Observatories, near the expected time of superior and inferior conjunctions of the B8 Ia component. Following Copernicus and IUE observations by Plavec and Polidan (refs. 4, 5), in which a UV flux excess indicated the presence of a component hotter than the B8 star, photometric observations in Hα intermediate and narrow-band and u filters made by Dorren at Biruni in June 1979 near the expected time of eclipse of the B8 star revealed light variations similar to those found by Morgan and Elvey, suggesting an eclipse lasting about 20 days with depths of ~ 0.14 mag at $\lambda 6585$ and ~ 0.16 mag at $\lambda 3500$. Observations at Villanova were made by Dorren and Guinan during September and October 1979 at $\lambda 6585$ to investigate the possible eclipse of the unseen component. A decrease in light of about 0.08 mag was observed with minimum light occurring at orbital phase 0.57, calculated from the revised ephemeris:

$$T\,(\mathrm{Min}) = \mathrm{JD}2444035.0 + 180.^{d}55 \cdot E$$

which corresponds to the time of light minimum observed near the expected superior conjunction of the B8 supergiant component. The phase (0.57) at which the above minimum occurs is consistent with the published values of e and ω. However, observations made in April and May 1980 starting at orbital phase 0.75 reveal departures from the expected outside-eclipse light variation and suggest the presence of minima near phases 0.75 and 0.83. A re-evaluation of the photometric data indicates the possibility of a $\sim$26 day quasi-sinusoidal light variation with an amplitude of about $0^{m}\!.10$. This 26 day light variation is of the order of magnitude expected for the radial pulsation of the B8 supergiant star (ref. 6). It is interesting to note that there is evidence for pulsation in β Orionis, which is of the identical spectral type (ref. 7). A check star, 16 Sgr was observed on 6 nights; no variation above the level of 0.015 mag was found, indicating that the comparison star 15 Sgr is not the source of the variations. The situation is further complicated by the fact that in an orbit of such high eccentricity and with a supergiant component of radius $\gtrsim 70 R_{\odot}$, most of the light variation near zero orbital phase would be caused by the tidal distortion of the B8 star (see fig. 1), while an eclipse of the unseen component would be responsible for the light variation at phase 0.57, if the orbital inclination is sufficiently high for eclipses to occur.

The λ6585 light curve is shown in figure 2, together with the Hα index, formed in the usual way. The index is about 0.1 mag more negative than typical values for stars of the same spectral type, indicating strong Hα emission which, however, shows little phase dependence.

Two IUE high-dispersion long and short wave and 4 low-dispersion long and short wave IUE spectra were obtained by Guinan and Sion on 1979 September 24 UT near the expected time of the eclipse of the unseen component. The flux distribution, de-reddened using $E_{B-V} = 0.3$ derived from the λ2200 feature (ref. 8) is shown in figure 3 together with fluxes at $\underline{B}$ and $\underline{V}$ wavelengths (ref. 9), and in the infrared out to 10 μ (ref. 10). A fit using a model atmosphere of Kurucz (ref. 11) with blanketing included for the filtered wavelengths, corresponding to a temperature of $T_{eff} =$ 11,000°K and log g = 2.0, appropriate for a B8 supergiant, is also shown. The agreement is good and there is no indication of flux due to a hotter component, suggesting that if the system does contain such a component, it was either eclipsed at the time of the IUE observations, or the smaller component contributes little to the total light of the system. A better fit to the data could be obtained by assuming $T_{eff} = 11,500$°K and log g = 2.0 using the Kurucz model. It is interesting to note the strong deviations from black body behaviour in ultraviolet wavelengths exhibited by a star of a temperature appropriate for the B8 Ia spectral type. The Copernicus spectra* show the presence of a hot component at orbital phases 0.9 and 0.26 and its absence at phase 0.5. Skylab UV observations at phase 0.7 (ref. 12) indicate a maximum flux level of $\sim 1.7 \times 10^{-10}$ ergs cm^{-2}sec^{-1}Å^{-1} at λ1800, a factor of $\sim$6 below the observations shown in figure 3.

The UV spectrum of μ Sgr is extremely rich in absorption lines. Those of Fe II are most numerous, and the Mg II h and k lines are particularly prominent. Lines of

* Polidan, R.S., private communication

Fe I, Si II, Al III, Mg I, He I, He II and Lyman α have also been identified. P Cygni profiles of Si IV and C IV with blue-shifted absorption components are also present, indicating mass loss, and are shown in figure 4. From the measured terminal velocity, $v_\infty \sim 200$ km/sec, obtained from the shortward edge of the absorption profile, an upper limit of $\dot{M}_{max} = 1.0 \times 10^{-5} M_\odot/yr$ for the mass loss rate is found using the relation (ref. 13):

$$\dot{M}_{max} = \left(\frac{L}{cv_\infty}\right) = 7 \times 10^{-12} \left(\frac{L}{L_\odot}\right)\left(\frac{3000}{v_\infty}\right) M_\odot/yr$$

where c is the velocity of light and the total luminosity, L, of the B8 star is $\sim 3.7 \times 10^{38}$ ergs/sec if an absolute bolometric magnitude of ~ -7.7 is assumed. Such a rate would only be achieved if there were a complete transfer of photon momentum in a single scattering. Thus the mass loss estimate that we obtained is consistent with the value of $1.1 \times 10^{-6} M_\odot/yr$ obtained by Barlow and Cohen (ref. 10) from IR observations.

The presence of a $9^m\!.9$ B3 companion of μ Sgr, if assumed to be a main-sequence star, provides a second estimate of the B8 star's luminosity, yielding a value close to the above, and hence a distance to the system of $\sim$1 kpc.

Photoelectric observations of μ Sgr are continuing in an effort to improve our understanding of this unusual binary system. A more detailed study will be published with Plavec and Polidan.

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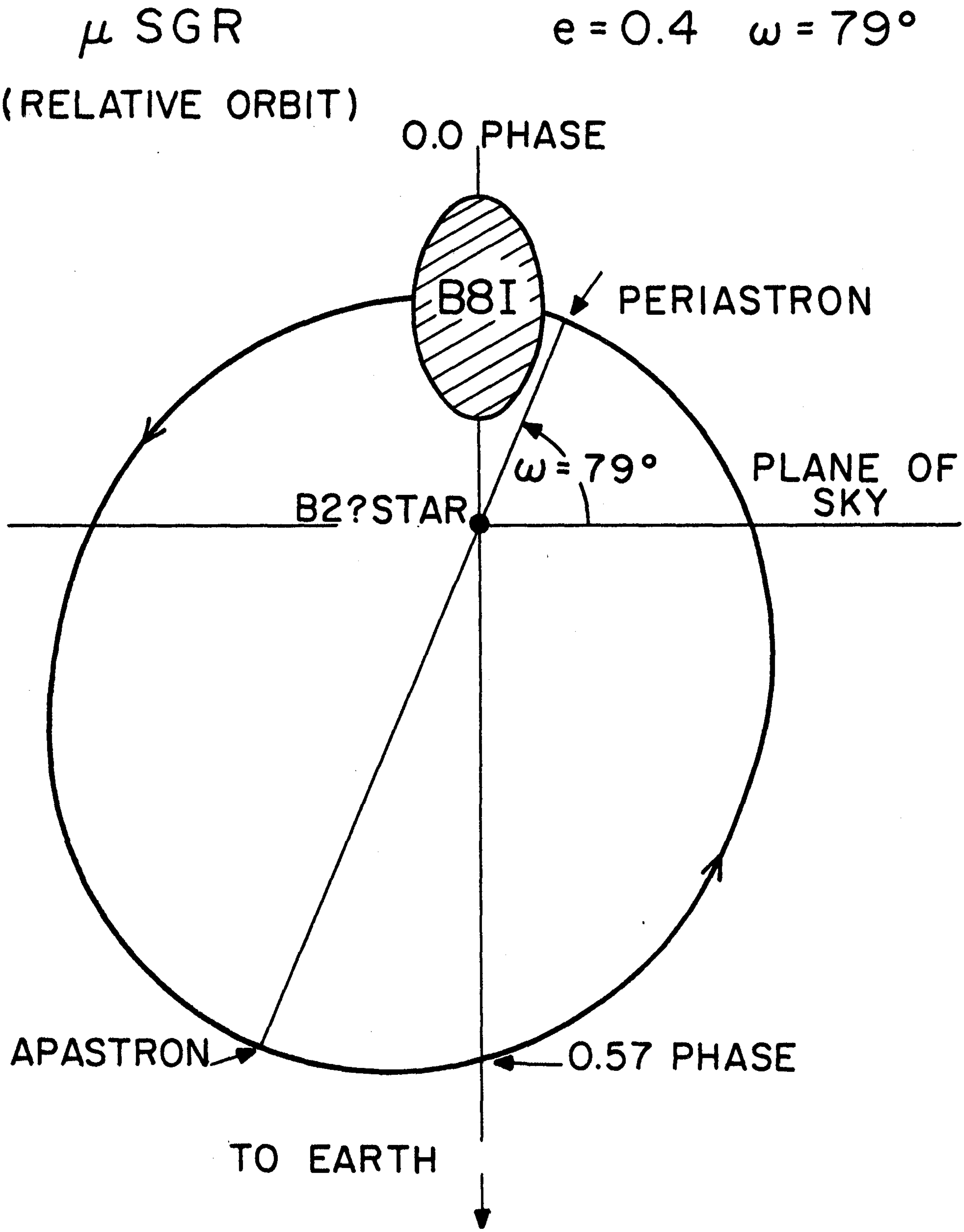

Fig. 1: The relative orbit of μ Sagittarii, approximately to scale

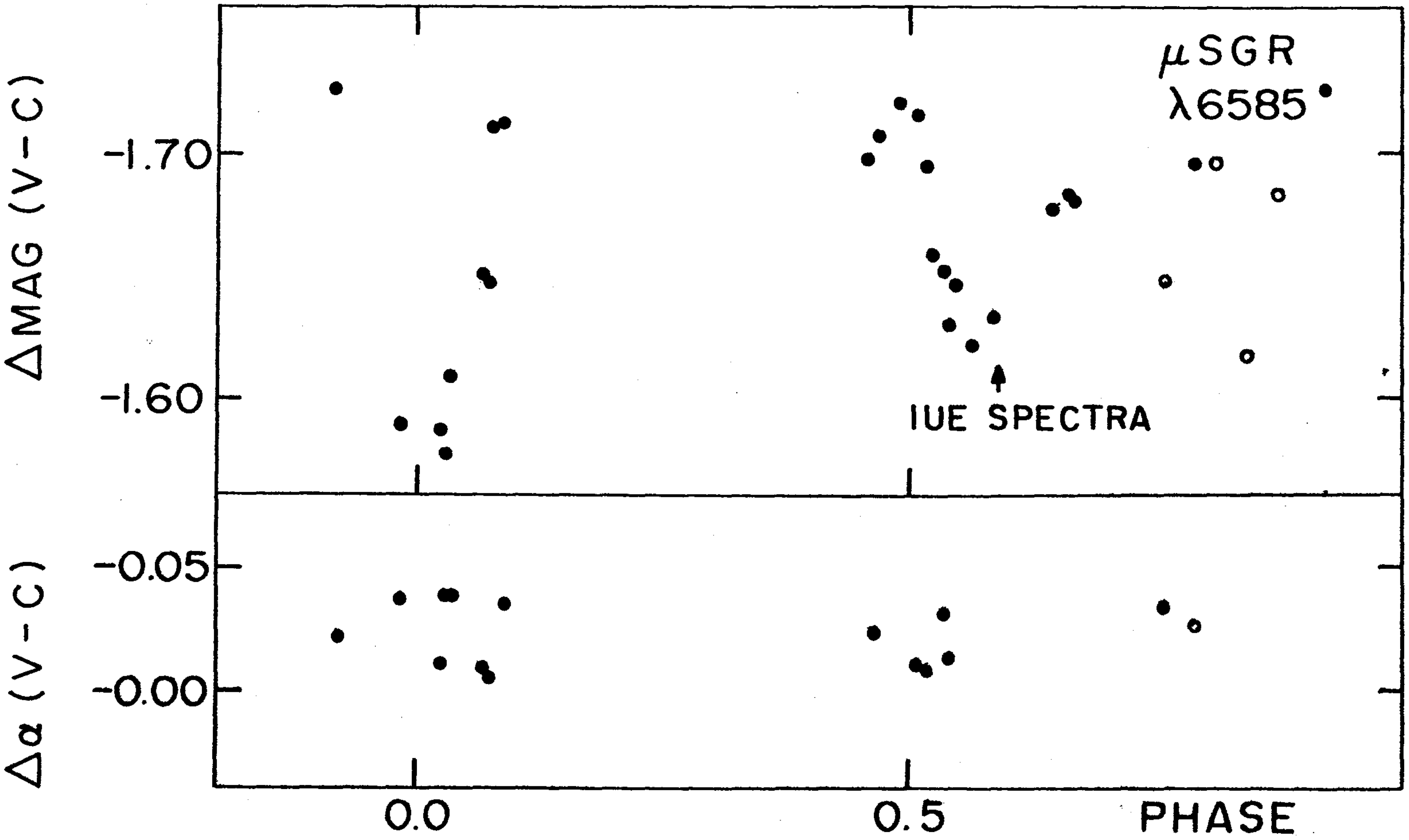

Fig. 2: λ6585 intermediate-band light curve and differential α-index, as a function of orbital phase.

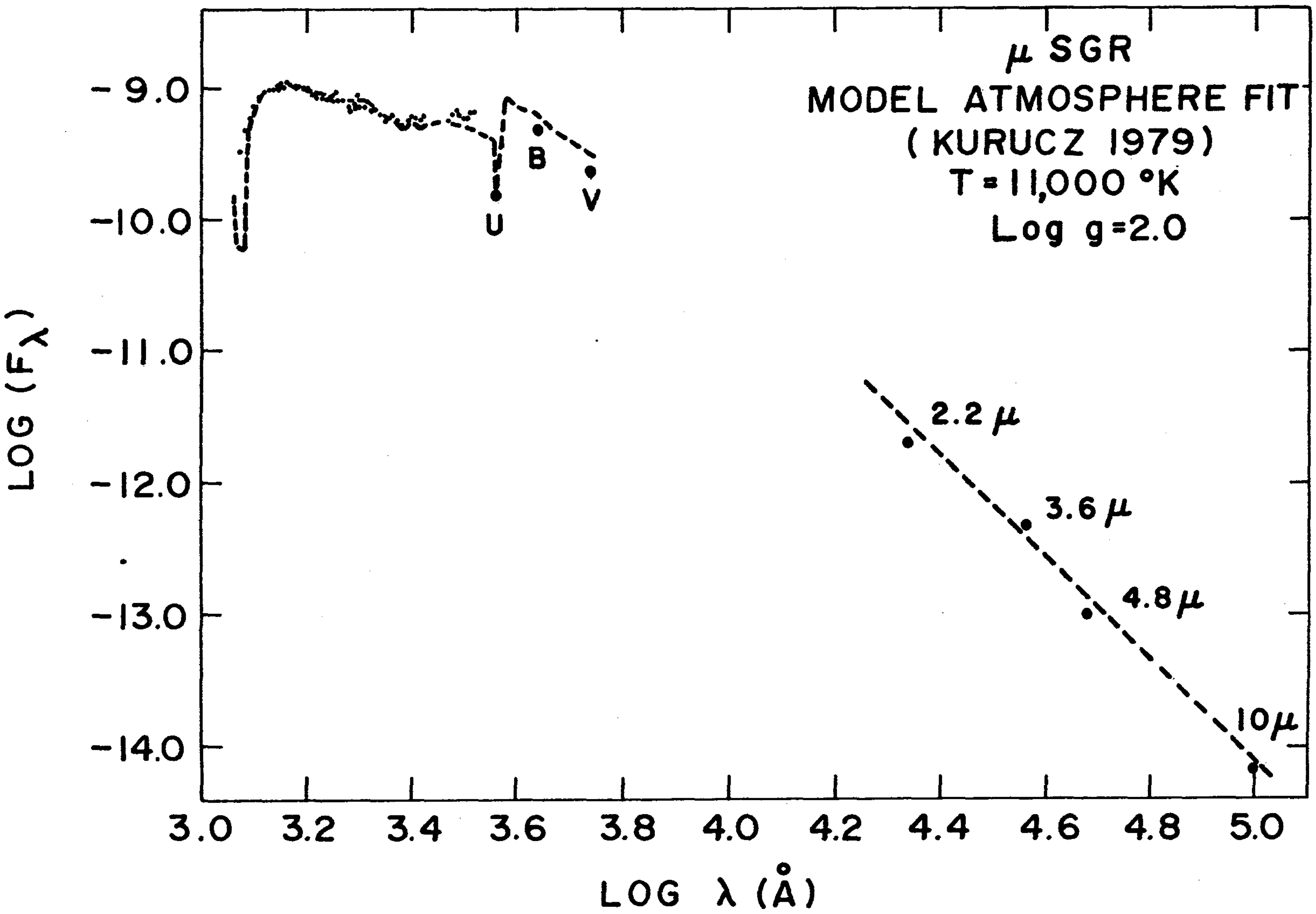

Fig. 3: Absolute flux (in ergs. cm^{-2}. sec^{-1}. $Å^{-1}$) as a function of wavelength, from 0.1 to 10 μ. The broken line is a fit using a Kurucz model atmosphere with T_{eff} = 11,000°K and log g = 2.0

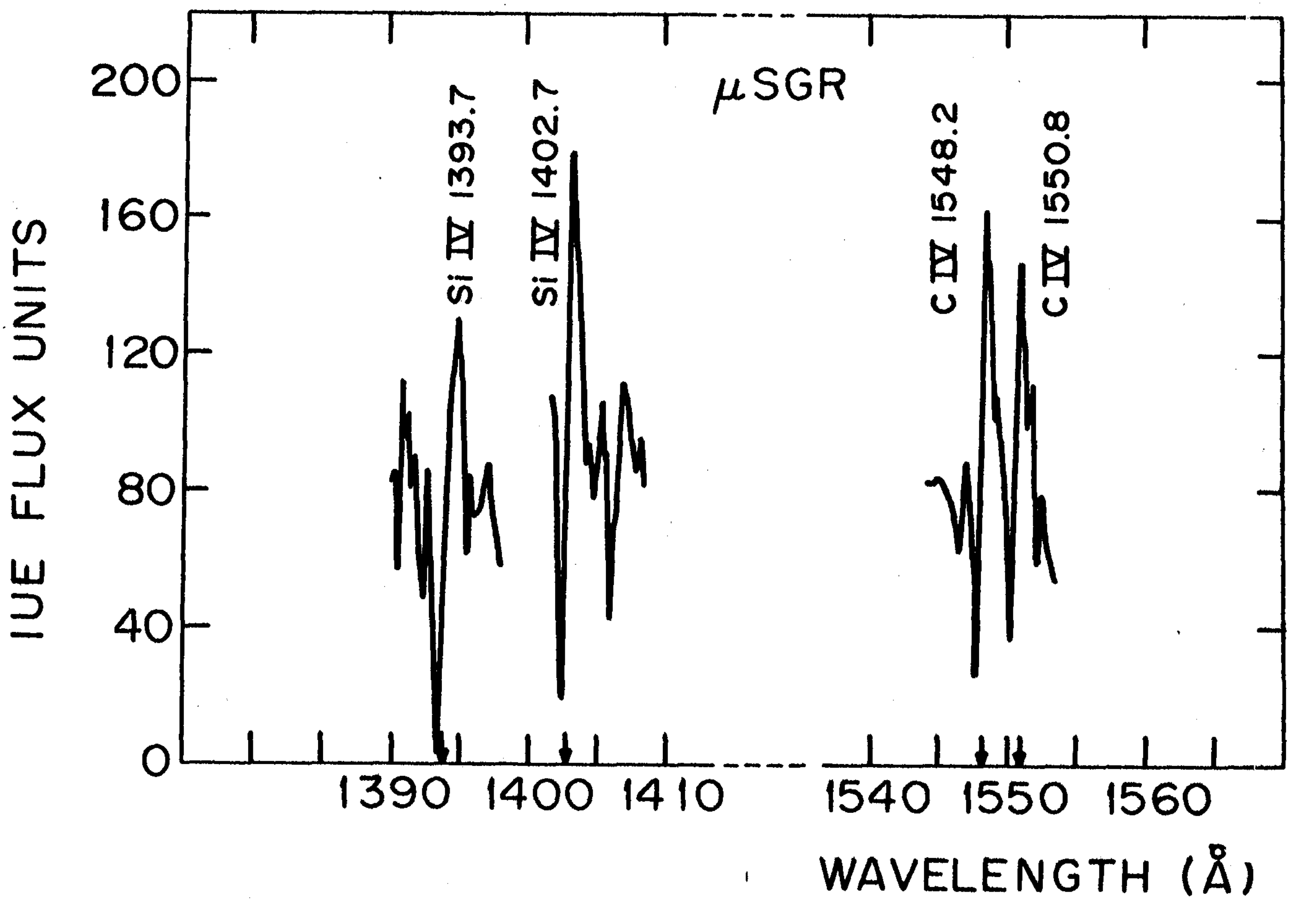

Fig. 4: P Cygni profiles of Si IV and C IV. The arrows indicate the positions of the rest wavelengths.